MAT-231
Lightweight Metals Core Program Introduction

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LMCP OVERVIEW

MAT-231
Lightweight Metals Core Program (LMCP) Overview

Timeline

- Lab Call Award – September 2020
- Kickoff – November 2020
- End – September 2023
- 50% Percent complete

Budget

- Total project funding $15M/3 years
- Funding for FY 2022 - $5M

Lightweight Metals Core Program Overview			
	Title	**# of Projects**	**FY22**
Thrust 1	Selective Processing of Aluminum Sheet Materials	3	$1,300,000
Thrust 2	Selective Processing of Aluminum Castings	3	$1,450,000
Thrust 3	Selective Processing of Magnesium Castings	2	$1,100,000
Thrust 4	Crosscutting Thrust - Characterization, Modeling and Lifecycle	7	$1,150,000

Barriers and Technical Targets

- **Materials Performance and Cost** limit the penetration of lightweight Al and Mg alloys into the entire range of vehicle*
- **New Alloy** development is slow and costly*
- **Recyclability** is complex due to large number of different alloys*

*USDRIVE Materials Technical Team Roadmap, October 2017

Partners

- Program Lead
  - Pacific Northwest National Laboratory
- Partner Laboratories
  - Oak Ridge National Laboratory
  - Argonne National Laboratory
- Industry Engagement
  - Select materials and experimental prototypic parts provided by OEMS
  - Informal support and guidance from OEMS, Tier 1s and Material suppliers
  - CRADAs planned for future years

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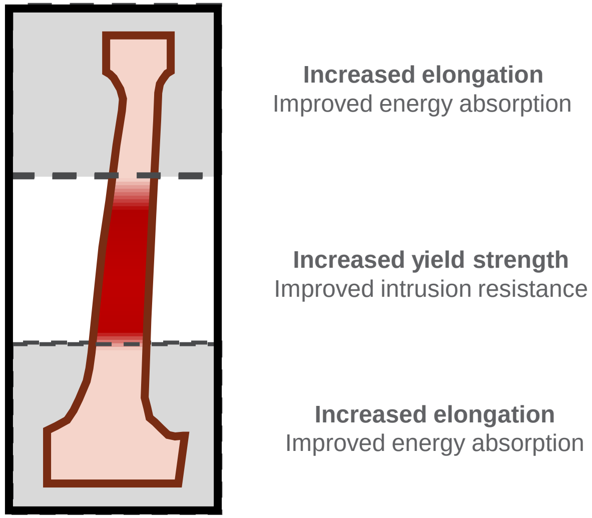
Lightweight Metals Core Program
The Opportunity

Put the right "property" in the right place

- Sheet-metal and cast components are often engineered to meet the performance requirements of only a select region on a part
- If just that region could be improved, the rest of the component could reflect that relaxed structural requirement (thinner walls or lower strength lightweight alloy)
- New local processing methodologies may be able to produce extraordinary properties in strength, ductility, durability or energy absorption just in selected areas of a part.
- Can we use this strategy to enable greater use of lightweight alloys, to substitute a low-cost bulk material for complex, joined, multimaterial assemblies, or to reduce the number of different alloys or components to simplify recycling.



The Overall Objective

The LMCP brings together PNNL, ORNL, and ANL with the goal to develop scalable and cost-effective processing methods to locally enhance the properties of aluminum and magnesium to enable broader implementation of lightweight alloys in vehicles.

LMCP OVERVIEW

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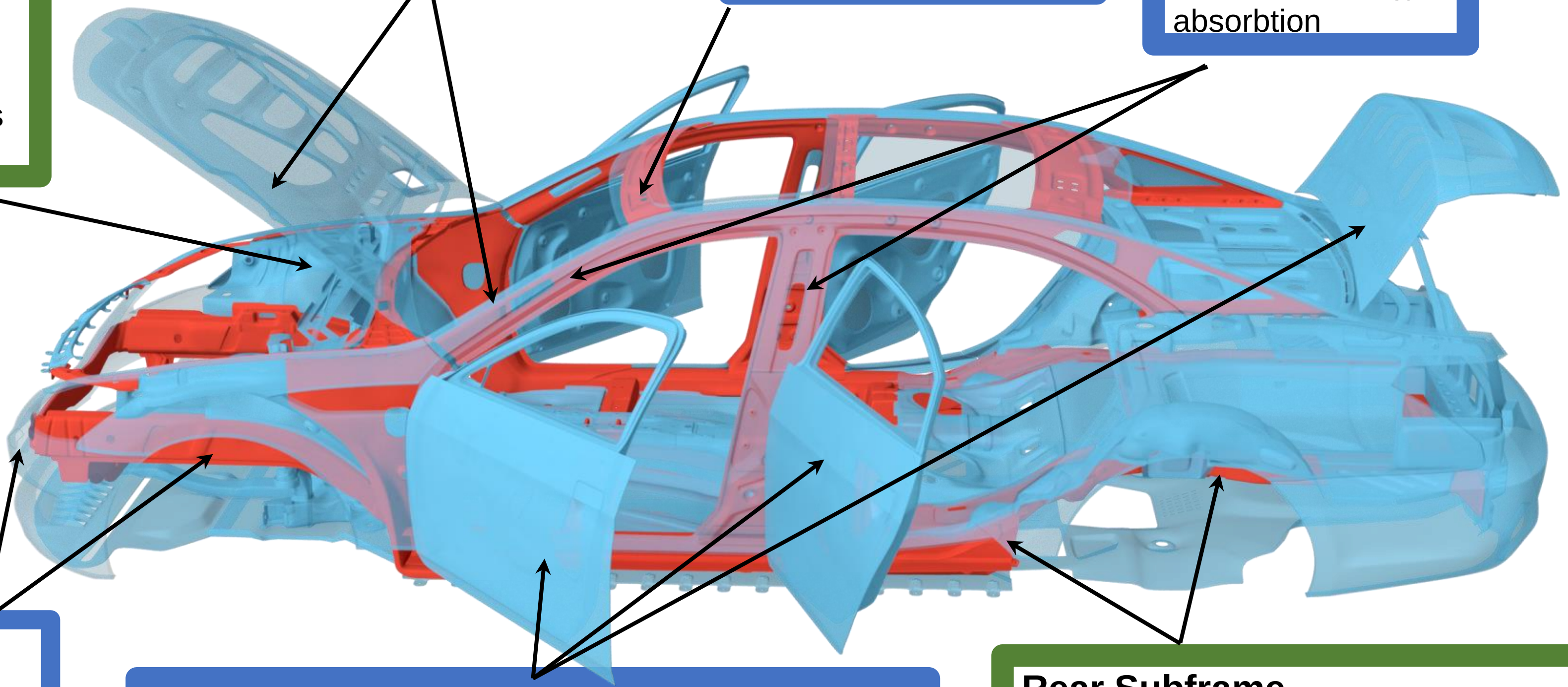
Opportunities for Heterogeneous Materials

Shock Towers
Need durability and strength especially where interfaced with other components or in high stress corners and features

Inner support structures for closures and Interior
Strength stiffness to support closures, need local durability in fatigue

Roof Header, roof rail, door sill
Need high strength for load transfer but ductility locally for forming

A-B-C Pillars
Need strength in the center, ductility on the top and bottom for energy absorbtion



Aluminum Sheet

Aluminum Casting

Magnesium Casting

Front Crash Structures
Need strength and ductility for energy absorption

Closures
Need strength for dent resistance but local high ductility for deep draw features and hemming

Rear Subframe
Need durability and strength in high stress areas but ductility toughness and energy absorption in crash

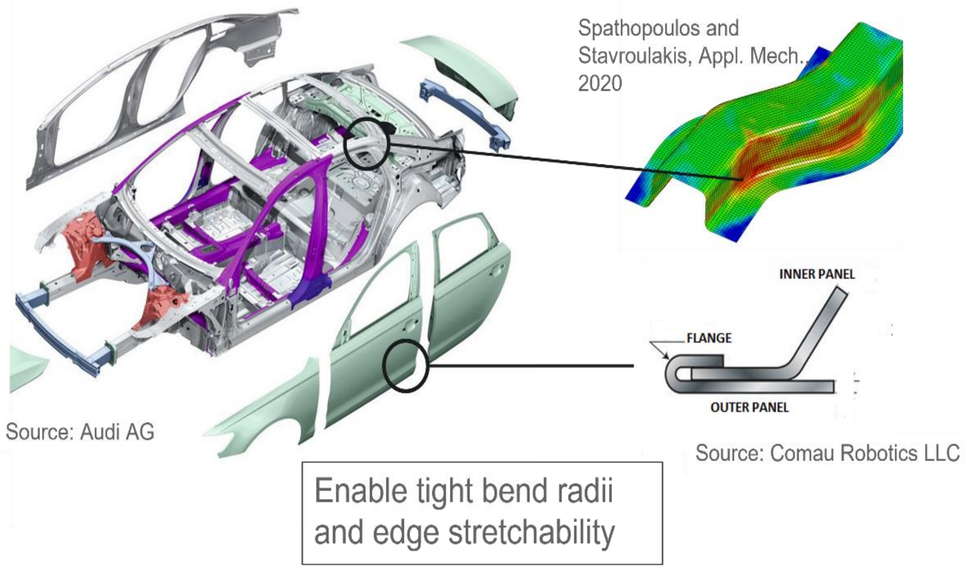
Can we reduce part and alloy count and enable greater use of lightweight materials by giving single parts the ability to satisfy location dependent demands ?

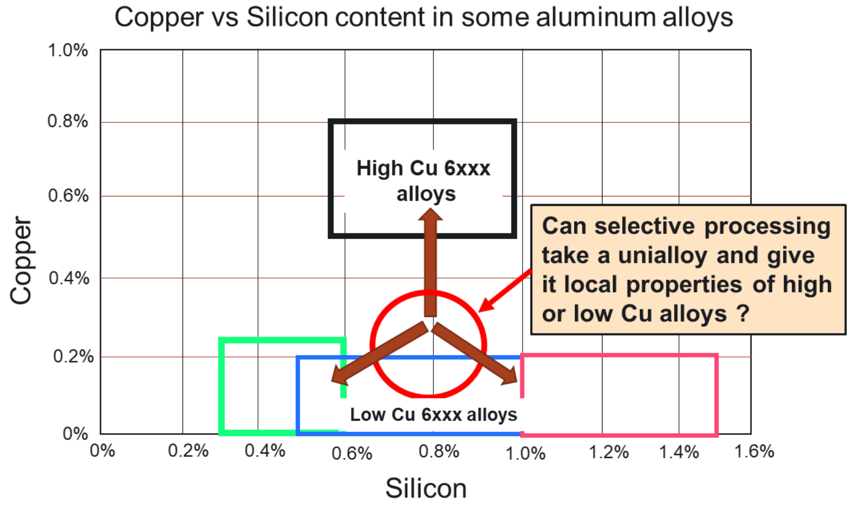
Relevance / Impact

The Impact of Intentionally Heterogeneous Materials

If we can make parts with local customized properties, what impact to lightweighting and energy/CO_2 savings can be possible?

- Downgauging
  - In one LMCP project a case study indicated that if T6 could be made hemmable, then a 17% thickness reduction over the paint baked T4 equivalent panel may be possible at the same dent resistance - Material/weight and cost savings
- "Uni-Alloy" Concepts - De-risk a complicated supply chain
  - If we can use T6 for everything, T4 shelf life problems go away, T6 can be stored through a crisis!
  - And if we don't need paint bake response maybe we can reduce high copper alloys (lower cost & corrosion)
  - Reduce current 4 recycle streams (HiCu / LowCu 6xxx, HiMag / LowMag 5xxx) to three, or less.
  - A single cast alloy might be possible that can be locally modified to target specific properties
- Enable higher recycled content in both sheet and castings
  - Selective processing can make local properties of high impurity alloys better than the premium choice.
  - Higher Fe tolerance in cast alloys could allow for more recycled content in the casting, maybe 100% recycled (no virgin material)?
  - Recycle grades for sheet applications?





Technical Objective and Approach

Lightweight Metals Core Program –
Intentionally Heterogeneous Materials

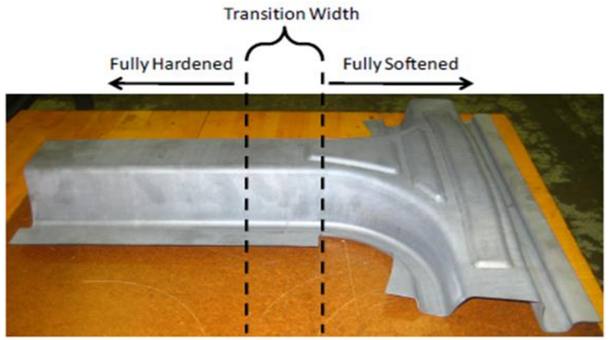
Core Program Technical Objective

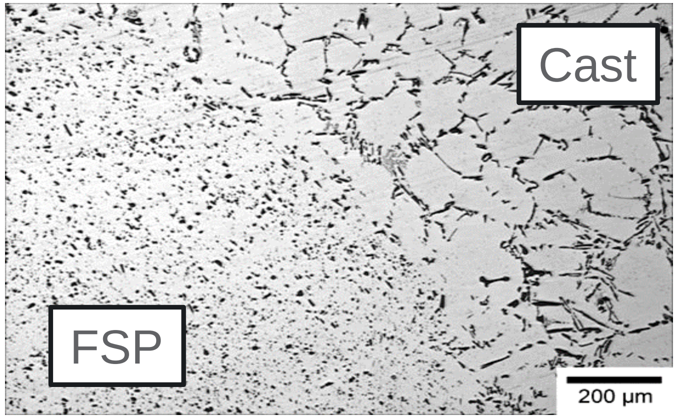
Combine multi-scale modeling and novel processing technologies to locally modify and improve material properties using

- Solid phase processing
- Additive manufacturing
- High intensity thermal and thermo-mechanical treatment

Key Fundamental / Scientific Questions

- **How far can commercial materials be improved if processed far-from-equilibrium through high shear Solid Phase Processing, high intensity thermal treatments or through rapid solidification (AM)**
- **How does microstructure and therefore properties, evolve through the processing route**
- **How are property gradients developed and controlled in the process**
- **How does the selective process influence the local properties such as later response to paint bake, and how does this influence the global performance**
- **What is the fundamental understanding needed to make a process stable and robust so it can be transitioned to industry**





Time at 180 °C (hr)	Steady State Die Temperature (°C)								
	410	430	440	450	475	481	495	520	532
1.3	59	59	58	64	65	67	70	72	75
2.5	62	67	71	75	79	80	79	83	87
5	66	68	75	79	88	86	91	92	92
10	69	71	83	86	93	94	96	96	98
20	65	70	85	85	92	96	96	92	93

6082	YS (MPa)	UTS (MPa)	U.E. (%)
Industry T5	230	270	8
Industry T6	260	310	8
ShAPE T5	**283**	**314**	**10.5**
Milestone	>265	>310	>10

LMCP Approach

Advanced Process Technologies: 1) Solid-Phase Processing, 2) Additive Manufacturing, 3) High-Intensity Thermal Treatments

Thrust 1

Localized Property Enhancements for Sheet Aluminum Applications

- Produce sheet with variable local properties, or locally modify formed sheet components to enhance properties in select regions for a component.
- Three (3) projects focused on methodologies to control sheet microstructure in 5000, 6000, 7000 series aluminum to tailor the right property in the right place.

Thrust 2

Localized Property Enhancements for Cast Structural Aluminum Applications

- Improve microstructures, and therefore properties, selectively applied and integrated with the fabrication process, and optimized for heat treatment.
- Three (3) projects aimed at creating wrought like microstructures and properties in local regions of aluminum-silicon castings.

Thrust 3

Localized Property Enhancements for Cast Magnesium Applications

- Develop local surface modifications to mitigate corrosion, and methodologies to modify the ductility, strength and creep performance of magnesium castings.
- Two (2) projects to that will enhance the integrity and durability of magnesium castings through localized microstructural improvements to surface properties.

Supportive Thrusts: Characterization, Testing and Computational Modeling

TRL-2 Technology Concept → **TRL-4 Component Validation**

Accelerating Development of Advanced Lightweight Metals

Approach

Lab Collaboration and Coordination

Pacific Northwest National Laboratory

Oak Ridge National Laboratory

Argonne National Laboratory

Thrust 1
Aluminum Sheet

Thrust 2
Aluminum Castings

Thrust 3
Magnesium Castings

1A PNNL
1B ORNL
1C1 PNNL
1C2 ORNL

2A1 PNNL
2A2 ORNL
2B PNNL
2C ORNL

3A1 ORNL
3A2 PNNL
3B PNNL

- Common material sets
- Joint proposals to T4
- Biweekly project meetings across labs

User Proposal Process

Crosscutting Thrust (Thrust 4)
Advanced Characterization and Computation

7 to 10 awarded projects per year leveraging advanced computation and characterization resources at PNNL, ORNL and ANL

Integrated Projects

C3 - Material Life Cycle Strategy (led by ANL)
C2 - Residual Stress Effects (led by PNNL)

Approach

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LMCP is a core program, but technologies being developed are filtered by an early look at feasibility, practicality, and cost / benefit

- LMCP worked from beginning to seek out advice from OEM, Tier1s and material suppliers on the challenges faced by greater insertion of lightweight alloys in BIW

OEMs and suppliers are giving us a practical filter on technology concepts

Ford GM RioTinto ECK INDUSTRIES ARCONIC Meridian

Each project is asked to do a yearly self evaluation of:
- Likelihood of research success
- Industrial acceptance and insertion point
- Performance improvement possible
- Impact on material lifecycle

- Selective processing concepts are discussed with stake holders and advice is solicited on manufacturing insertion point, potential cost avoidance when replacing existing processes with new, and preliminary estimates of cost.

Our self assessments keep us focused on commercialization and deployment

Project Impact Evaluation

Lightweight Metals Core Program – Project Impact Evaluation

To ensure the Lightweight Metals Core Program is successful in increasing the use of lightweight metals in the automotive industry, there will be an annual review of individual project impact. The overall project impact includes the likelihood of technical success, industrial acceptance, performance improvement, and impact on materials recycling. In order to help evaluate the overall impact, please write a short paragraph addressing each of these four topic areas. To help with this, several questions and discussion points are included.

Likelihood of Research Success
- What are the identified engineering barriers?
  - Describe the plan to overcome the identified barriers and the alternative paths that will be used if the primary path is not successful.
- What are the identified science barriers?
  - Describe the research plan to understand the scientific barriers and the checkpoints to validate the path forward.
  - Describe the alternative paths if the proposed path forward is not scientifically viable.
- Do you have a theoretical basis for development, or is it primarily experimental?
  - What model development is being done, and how predictive will it be?

Industrial Acceptance
- Where will this process technology fit into the manufacturing flow – at the material supplier, a tier 1 component maker, the OEM, somewhere else?
  - Why was this insertion point selected?
  - Have you discussed this with industry experts and what was their feedback?
- What are the changes to manufacturing process and infrastructure that will be needed for this technology to be adopted?
- What is the likely cost impact of this technology and how has that been determined?

Performance Improvement
- What is the performance baseline and why was it chosen?
- What is the performance improvement that is being targeted?
  - What is the improvement that is needed by industry to drive increased use of lightweight metals?
  - How does it compare to the ultimate theoretical potential improvement?
  - How does it compare to other currently available solutions?
- Are the improvements localized or general?
  - If local, what happens at the interfaces between the different areas?
- How stable are the improvements likely to be during the manufacturing and use phases?

Impact on materials lifecycle
- If successful, will this project improve the recyclability of the materials? Consider both during the manufacturing phase and at vehicle end of life.
- Will this project enable the use of more recycled materials? Why?
- Have you reviewed this project with an industry partner and/or the ANL lifecycle lead (Jeff Spangenberger)?

Summary

Department Of Energy - Vehicles Technology Program
Lightweight Metals Core Program

The question we hope to answer:

Can Selective Processing help put this together?

- **Faster**
- **At a lower cost**
- **With less embedded carbon**
- **With fewer different materials**
- **With fewer different parts**
- **With easier recyclability**

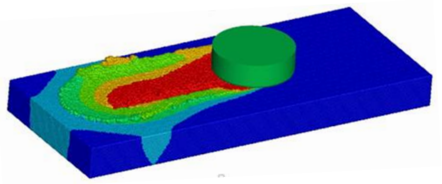
And can it help to reach our target of a 25% glider weight reduction at less than $5 / kg-saved by 2025

Approach

LMCP Projects Presented Today

- 8 projects within the research thrusts
  - Three projects have subtasks at different labs
  - Crosscutting Thrust (T4) projects awarded in FY22 in support of research projects will be summarized in the individual presentations

- Two projects that crosscut all thrusts
  - Residual Stress Characterization, Prediction, Optimization (PNNL $250k)



  - Material lifecycle (ANL $150k)

    Evaluate the benefits and challenges of multi-property materials to the auto shredder and non-ferrous recycling industry

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Thrust 1. Selective Processing of Aluminum Sheet

Project	Title	FY22
1A	Sheet Materials with Local Property Variation (PNNL/ANL)	$500k
1B	Form-and-Print – AM for Localized Property Enhancement (ORNL)	$200k
1C1	High-Shear Thermomechanical Processing (PNNL)	$400k
1C2	Localized Thermal-Mechanical Processing (ORNL)	$200k
	Thrust Totals	$1,300k

Thrust 2. Selective Processing of Aluminum Castings

Project	Title	FY22
2A1	Local thermomechanical processing of die-cast aluminum alloys for improved fatigue and fracture toughness behavior (PNNL)	$400k
2A2	Power Ultrasonic Surface Processing of Die Cast Al Alloys (ORNL)	$200k
2B	High-intensity Thermomechanical Processes for Enhanced Strength, Fatigue Resistance and Ductility in Al Castings (PNNL)	$400k
2C	Cast and Print - AM for Localized Property Enhancement (ORNL)	$450k
	Thrust Totals	$1.45m

Thrust 3. Selective Processing of Cast Magnesium Alloys

Project	Title	FY22
3A1	Cast magnesium alloy surface modifications to improve the corrosion performance- Reactive Processes (ORNL)	$450k
3A2	Cast magnesium alloy surface modifications to improve the corrosion performance- Surface Alloying (PNNL)	$350k
3B	Local Thermomechanical Property Modification of Magnesium Castings via Solid-Phase Processing techniques (PNNL)	$300k
	Thrust Totals	$1,100k

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Thank you

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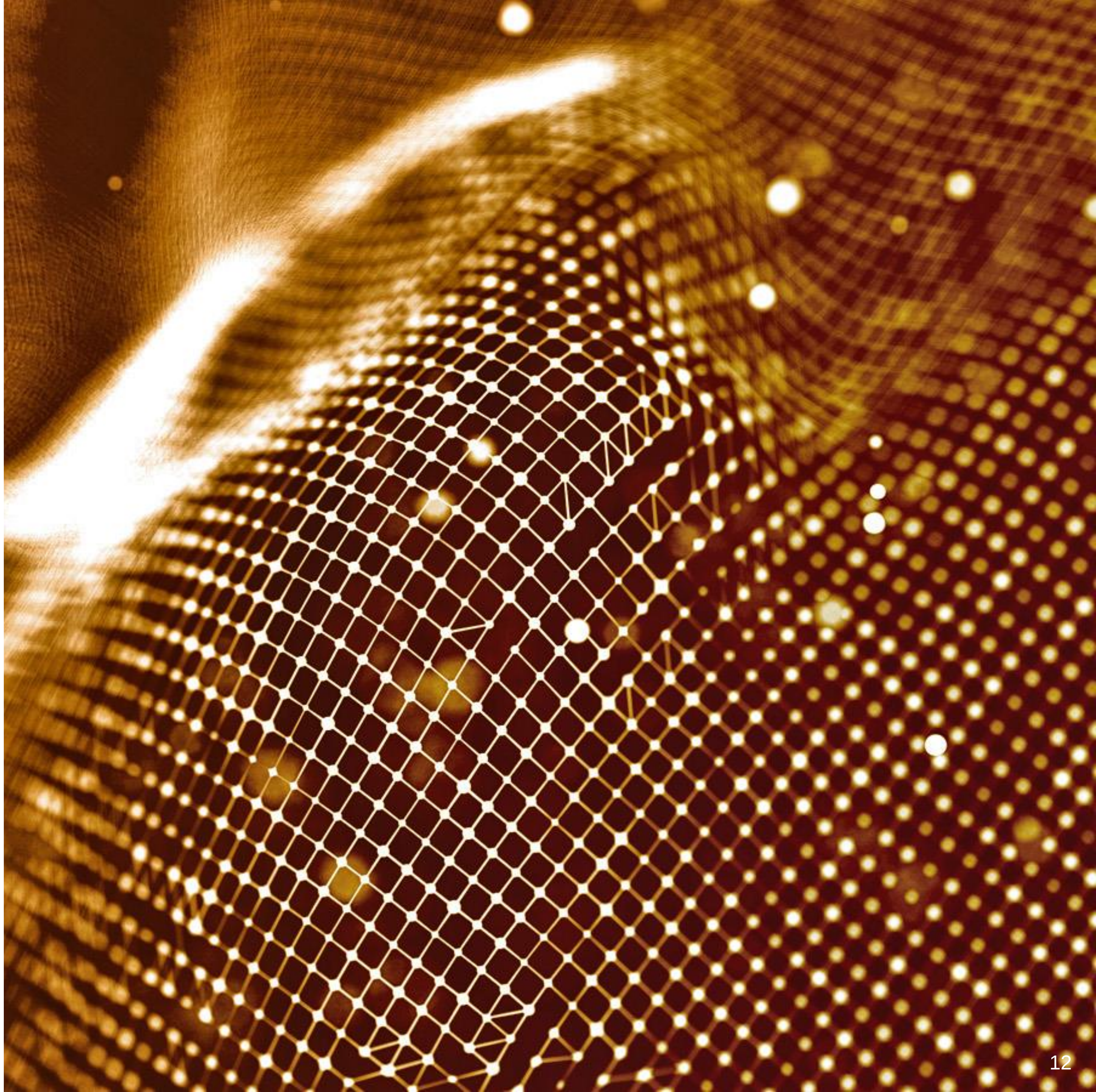

Backup Slides

LMCP Structure

Integrated collaboration between PNNL, ORNL and ANL


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Capabilities Leveraged

- **Solid Phase Processing Lab (PNNL)**


FSW, FSP


Cold Spray


ShAPE Extrusion

- **Manufacturing Demonstration Facility (ORNL)**

- **Synchrotron X-rays APS (ANL)**

- **HPC, Advanced Characterization (PNNL,ORNL,ANL)**

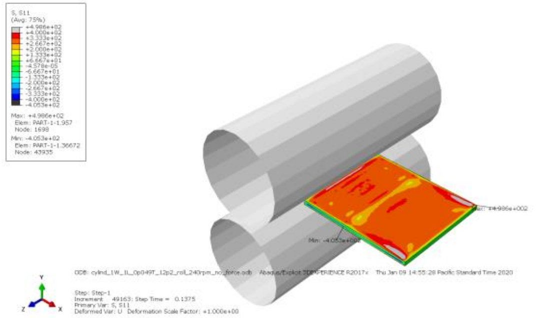
Publications / Presentations

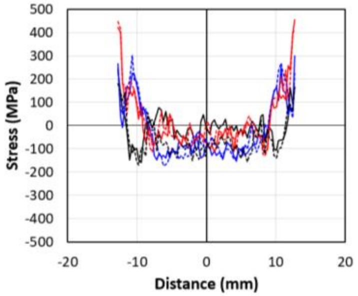
- B. Milligan, M. Komarasamy, A. Battu, T. Varga, A. Guzman, S. Whalen, “Multi-Alloy Aluminum Tubing via Shear Assisted Processing and Extrusion,’” Light Metals, pg. 289-293, 2022.
- M. Komarasamy, S. Whalen, B.S. Taysom, D. Herling, “Co-Extrusion of Dissimilar Al Alloys via Shear Assisted Processing and Extrusion,” Light Metals, pg. 308-313, 2022
- Nasim W., H. Das, S.S. Kulkarni, A. Rohatgi, D.R. Herling, G.J. Grant, and P. Upadhyay, et al. 2022. "Local Thermomechanical Processing for Improving Formability of High Strength Aluminum Sheets." In SAE Annual World Congress Experience, (WCX 2022), April 5-7, 2022, Virtual, Online. SAE Technical Papers, Paper No. 2022-01-0244. Warrendale, Pennsylvania:SAE International. PNNL-SA-168320. doi:10.4271/2022-01-0244
- Upadhyay P., H. Das, W. Nasim, and M. Efe. 03/09/2022. "Improved room temperature formability of high strength Al sheets using friction stir processing.“ Poster Presented at TMS 2022
- Avik Samanta, Hrishikesh Das, David Garcia, Robert J. Seffens, Timothy J. Roosendaal, Anthony Guzman, Glenn J. Grant & Saumyadeep Jana (2022). Microstructural Modification of a High-Pressure Die-Cast A380 Alloy Through Friction Stir Processing and Its Effect on Mechanical Properties. In: Eskin, D. (eds) Light Metals 2022. The Minerals, Metals & Materials Series. Springer, Cham. https://doi.org/10.1007/978-3-030-92529-1_101
- Avik Samanta, Robert J.Seffens, Hrishikesh Das, Anthony D.Guzman, Timothy J.Roosendaal, DavidGarcia, Miao Song, Glenn J. Grant Saumyadeep Jana, Microstructure-refinement–driven enhanced tensile properties of high-pressure die-cast A380 alloy through friction stir processing, Journal of Manufacturing Processes, Volume 78, June 2022, Pages 352-362
- Katherine Rader, Jens Darsell, Jon Helgeland, Nathan Canfield and Aashish Rohatgi, Ultrasonically-Induced Microstructural Refinement During Casting of an Al-Si-Mg Alloy.. TMS 2022 Poster
- Katherine Rader, Jens Darsell, Jon Helgeland, Timothy Roosendaal, Ethan Nickerson, and Aashish Rohatgi, Ultrasonically-Induced Microstructural Refinement to Improve Strength of an Al-Si-Mg Casting.. MS&T ’22 Symposium on Development in Light Weight Alloys and Composites
- Katherine Rader, Aashish Rohatgi, Jonova Thomas, Andrew Chuang, Dileep Singh and Adrian Sabau, In-Situ Diffraction of Ultrasonically-Modified Phase Evolution in a Ternary Al-Si-Mg Alloy.. MS&T ’22 Rustum Roy Symposium: Processing and Performance of Materials Using Microwaves, Electric and Magnetic Fields, Ultrasound, Lasers, and Mechanical Work
- Pang, Qin, et al. "Water Adsorption and Surface Atom Detachment on Zn, Ce-Doped Mg Al, Surfaces." Magnesium Technology 2022, Petra Maier Steven Barela Victoria M. Miller Neale R. Neelameggham (2022): 291.
- J. Jun, G. L. Knapp, Y. F. Su, Y. C. Lim and A. Plotkowski “Effect of Laser Surface Treatment on Corrosion Behavior of AZ91D Mg Alloy”, Virtual Oral Presentation TMS 2022.
- G. Jang, J. Jun, Y. F. Su and M. P. Brady, “Effect of CO2 Annealing Treatments on Corrosion Behavior of AZ91D Mg Alloy”, Virtual Poster Presentation TMS 2022.

T4 Integrated Projects

Residual Stress Characterization, Prediction, Optimization

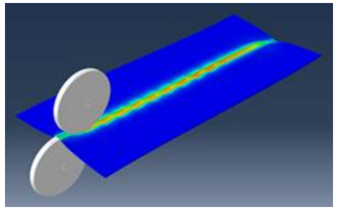
- **Project C2 - Residual Stress Effects (led by PNNL)**

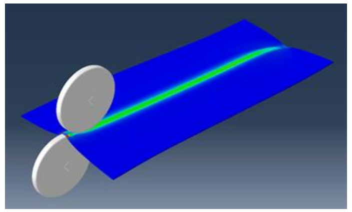




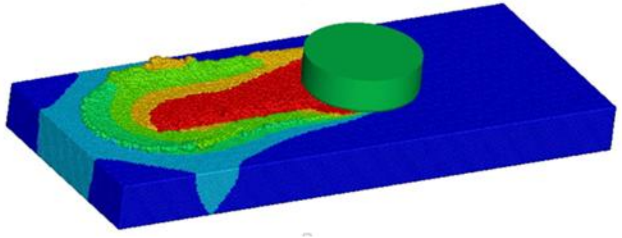
Objective:

- Develop a combined experimental-computation framework to accurately measure and predict residual stresses resulting from local property enhancement processes.
- Focus on measuring and predicting the residual stresses at the macro-scale.
- Help establish the optimum process parameters to reduce residual stresses and guarantee dimensional stability.
- Explore opportunities to take advantage of residual stresses…for example compressive residual stress induced by ultrasonic processing





- This topic area leverages characterization capabilities across labs (DIC hole drilling and XRD at PNNL, XRD and Neutrons at ORNL, and APS at Argonne)



Residual stress measurements being conducted both at the macro scale (Hole drilling + Digital Image Correlation (DIC), neutron diffraction) and micro scale

The T4 Integrated Projects

Project C3 - Material Life Cycle Strategy (led by ANL)

Jeff Spangenberger (PI)
Jessica Durham

<u>Objective:</u>

- Evaluate the benefits and challenges of multi-property materials developed in the Lightweight Materials Core Program (LMCP) to the auto shredder and non-ferrous recycling industry
  - Simplification of materials separation due to a reduction in alloys used in vehicles
  - Increased adoption of these materials increase value to the recycler and increase recycling rates

<u>Example Projects contributing concepts:</u>

  - 1C1,1C2 if we can go to a smaller set of hardened alloys and locally modify for forming, we might be able to eliminate high Cu alloys simplifying the recycle stream
  - 1A single alloys with variable properties to replace multimaterial components, and enabling recycle grades as feedstock billets for ShAPE processing to hydroformed tubulars and sheet/strip
  - 2A Can selective processing enable the use of high Fe “recycle” grades as feedstock for HPDC parts?